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DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
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FLUORESCENT LAMPS

Contents

I. Introduction

The development of the new fluorescent lamps and their possibilities for general and decorative lighting purposes have brought many requests for information to this Bureau. This letter circular has been prepared in answer to such inquiries. It contains information which has been accumulated in answering these letters, but is not an exhaustive treatise on the subject.

II. Work of the National Bureau of Standards on Fluorescent Lamps

The development of the fluorescent lamps by the manufacturers is progressing so rapidly that the Bureau has as yet made no extensive study of the comparative efficiencies or costs of operation of fluorescent lamps and incandescent lamps. Such information is given by the manufacturers and is referred to below. A letter circular on Fluorescence and Phosphorescence, LC-550, was issued by the Bureau under date of April 1, 1939. This circular is available, without cost, upon written request to the Bureau.

III. Description of the Lamps

The present commercially available fluorescent lamps are made in the form of a tubular bulb with a filament-type electrode sealed in each end. A base, having two pins for making electrical contact in the special sockets used, is cemented onto each end of the tube.

Many types of electric-discharge sources of light have long been known, the more common ones being those using neon, mercury and sodium vapor. The fluorescent lamp is also an electric-discharge source, but of notably different type. It is essentially a mercury-vapor lamp with a small amount of argon gas to facilitate starting. The electrical characteristics, current density, vapor pressure and voltage are so regulated that the resultant discharge produces as much energy as possible in the ultraviolet region at 253.7 mu. This ultraviolet energy activates the "phosphor", that is, the material which is coated on the inside of the bulb. The activated phosphor emits energy in the visible region (fluorescence), the spectral composition of the emitted energy depending upon the particular phosphor being used.

G. E. Inman[1] has published a comprehensive paper giving the spectral energy distribution and the trichromatic coefficients (ICI system) as well as the luminous efficiencies and physical characteristics of lamps having illuminant colors designated as blue, green, gold, pink, red, white and daylight. The phosphors and the color designations given by one of the manufacturers are listed below:

Phosphor	Color Designation
Calcium tungstate	Blue
Magnesium tungstate	Blue-white
Zinc silicate	Green
Zinc beryllium silicate	Yellow-white
Cadmium silicate	Yellow-pink
Cadmium borate	Pink

[1] Transactions of the Illuminating Engineering Society 34, 65 (1939).

The luminous efficiencies given by Inman for fluorescent lamps range from 3 to 70 lumens per watt depending on the color. The efficiencies of gas-filled, incandescent-filament lamps (common household sizes) vary from about 10 to 17 lumens per watt depending upon the size in watts. The "daylight" and "white" fluorescent lamps most commonly used for illumination purposes have 2 to 3 times the luminous efficiency of the usual incandescent lamps, including the approximately 20 per cent of the total power consumed in the auxiliary.

The "white" lamp manufactured when Inman published his paper in January 1939 had a color temperature of about 2800°K. This has now been increased to about 3500°K in the newer "white" lamps. The color temperature of the "daylight" fluorescent lamp is about 6500°K which is close to natural daylight from an overcast sky or from sun plus blue sky on a horizontal surface.

IV. General Information

The fact that the mercury arc emits energy in the short-wave ultraviolet region of the spectrum known to be harmful to the human eye has supplied the basis for a rumor that the fluorescent lamp itself is harmful. Measurements made in the Radiometry Section of the National Bureau of Standards[2] have shown, however, that the harmful energy is used only to activate the phosphor and does not penetrate appreciably the glass tubing, which is highly opaque to it. Therefore the fluorescent lamp is free from injurious ultraviolet radiant energy.

Fluorescent lamps, in common with all electric-discharge sources, require auxiliary equipment. This auxiliary consists of two principal elements (1) an iron-core choke coil which limits the arc current and (2) a starting switch which momentarily closes and then opens the electrode heating circuit. Each lamp requires a separate auxiliary (some manufacturers mount multiple lamp auxiliaries in a single metal container). Specifically designed auxiliaries are required for each wattage size, each frequency, and each voltage range.

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[2] Radiation from Fluorescent Lamps. Technical News Bulletin of the National Bureau of Standards No. 286, February 1941. Also Journal of the Optical Society of America 31, 280 (March 1941).

Fluorescent lamps <u>must</u> <u>not</u> <u>be</u> <u>directly</u> connected to the electrical circuit. The auxiliary equipment which is designed to operate the lamp is made for operation on the various commercial voltages and frequencies.

Any lamp operated on an alternating-current circuit has a non-uniform light output caused by the cyclic variations in current. With incandescent filament lamps, flicker is not noticeable, except in low-wattage lamps operated at low frequency (usually below 50 cycles), because sufficient energy is stored up in the glowing filament to bridge the periods when no current is flowing. In fluorescent lamps, where practically no energy is thus stored, the light drops almost to zero along with the current between each half cycle, causing flicker and stroboscopic effects, particularly in evidence when viewing moving objects (such as rotating machinery and tools in manufacturing plants). Fortunately most of the fluorescent powders used in these lamps have a slight persistence of glow (phosphorescence) which helps to reduce flicker, the reduction being dependent on the phosphor used.

Flicker and stroboscopic effects with fluorescent lamps are most marked where lamps are burned singly, and in such cases little can be done to improve the condition. However, where two or more lamps are housed in a single unit, or even used close together in individual units, it is possible to minimize flicker considerably by manipulating the current to each lamp so that the high point in the current cycle (also of light output) of one lamp occurs simultaneously with the zero point in the current cycle of the other lamp. This out-of-phase condition is realized by burning lamps on two or more phases or by placing an appropriate condenser in the circuit of one or more of the lamps in a given installation. Special auxiliaries which produce this out-of-phase condition are available for the fixtures which use two lamps.

A choke coil such as that in the fluorescent-lamp auxiliary, because of its inductive effects, introduces a low power factor. Electrical engineers use the term "wattless component" for the effect of this inductance. The wattless component does not register on wattmeters or watthour meters but does cause heating in the distribution system. The correction of this power factor is important to the public utility since a low-power-factor load interferes with the efficient operation of the distribution system. The user may inadvertently overload a circuit if he neglects to make allowance for the heating caused by the wattless component or the losses in the auxiliary equipment. There are on the market specially designed capacitors for correcting power factor. These are available both as a separate unit and as an integral part of the auxiliary.

Fixture manufacturers have formed an organization known as Fleur-O-Lier Manufacturers, 2116 Keith Building, Cleveland, Ohio, which will furnish information on fixtures designed for use with fluorescent lamps.

V. Bibliography

The fluorescent lamp is in a state of rapid development and the current literature should be consulted for the latest information. Articles appear in the Illuminating Engineer (formerly Transactions of the Illuminating Engineering Society), published by the Illuminating Engineering Society, 51 Madison Avenue, New York. Copies of this publication may be found in many libraries and separate copies are available from the Society. The Electrical World has also published a number of articles of interest on the subject of fluorescent lamps.

Bulletins and pamphlets on fluorescent lamps available for distribution are issued by the General Electric Company, Nela Park, Cleveland, Ohio; the Westinghouse Electric and Manufacturing Company, Lamp Division, Bloomfield, New Jersey; the Hygrade Sylvania Corporation, Salem, Massachusetts; the Consolidated Electric Lamp Company (trade name Champion lamps), Lynn, Massachusetts; and other manufacturers.

The following technical articles should be of interest to those seeking information as to the history and present status of fluorescent lamps:

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